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Hybrid Power System Modelling and Simulation

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Abstract - When two systems are hybridized with the addition of a storage device, the system's reliability increases dramatically. Even in this instance, enough battery bank capacity is necessary to supply electricity to the load on lengthy cloudy and non- days. As a result, in particular geographical places where the environment is acceptable, the appropriate sizing of system components is an important feature of hybrid power system hybrid models of renewable power generation. The planned research will determine whether such non-use is justifiable or whether using hybrid models in particular regions with acceptable conditions would be useful.
Keywords – PV Array, Wind Turbine, Solar Cell, Hybrid Power System

I. INTRODUCTION

Renewable Energy has surely come to the attention of the international community as being critical to our world's clean and safe future. Fossil fuels have a finite supply and contribute to pollution and global warming. There is widespread agreement that developing countries are among the primary contributors to global warming and pollution, as evidenced by various ongoing climate debates. India and China are two of these countries. According to a UNEP report, initiatives investing in renewable energy and improving energy efficiency in developing countries might cut emissions by 1.7 giga tonnes.Sea levels are rising, average world temperatures are rising, and extreme weather is becoming more common as a result of global warming climatic conditions. During the summer in India, persistent droughts are wreaking havoc on farmers. The monsoon season, on the other hand, is delivering more rain than ever before. Cyclones and other extreme weather events are becoming more common, with recent examples such as the one in Chennai having negative consequences. As a result, it is critical to eliminate the fossil fuel-based energy system and replace it with a sustainable, renewable energy system.

II. SOLAR ENERGY

Solar energy is generated by photovoltaic (PV) cells, which When exposed to sunshine, photons are converted to electricity. Photons from the Sun collide with the PV cell's semiconductor material, releasing electrons, that power the device. Each PV cell is linked together to form a solar panel array. A PV cell has two layers of silicon crystal-based semiconductor material. Because crystallized silicon isn't a particularly good conductor of electricity on its own, it's doped with impurities to improve conductivity. The bottom layer of a PV cell is commonly doped with boron (3 valence electrons), which interacts with the silicon to allow a positive charge to be generated (P). The top layer is doped with phosphorus (5 valence electrons), which forms a connection with the silicon and allows a negative charge to form (N). The P-N junction is the interface between the resulting "p-type" and "n-type" semiconductors.

The energy of sunshine entering the cell knocks electrons loose in both levels. The electrons desire to move from the n-type layer to the p-type layer due to the opposite charges of the layers, but the electric field at the P-N junction prohibits this. However, the presence of an external circuit provides the essential channel for electrons from the n-type layer to reach the p-type layer. This external circuit is made up of extremely tiny wires that run along the top of the n-type layer, and the electrons that flow through it produce electricity.

III. WIND ENERGY

Mechanical energy is transmitted to the rotor of an electric generator in a wind energy system, where it is converted to electrical energy. The rotor transfers the kinetic energy of the wind into mechanical energy, which drives the blades of the rotor. Through electromagnetic induction, the generator turns the mechanical energy from the rotor's rotation into electrical energy. Wind power generated depends upon:

- amount of air (Volume)
- speed of air (Velocity)
- mass of air (density)
- flowing through the area of interest (flux)

The losses experienced during the translation of kinetic energy to mechanical energy, as well as generator losses during the transmission of mechanical energy to electrical energy, have an impact on wind energy. The capacity factor Cf, which changes depending on wind speed and other natural conditions, is a percentage of the rated capacity. Windmill turbine efficiency rises as

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wind speed rises, but it begins to decline at very high speeds. As a result, there is a speed at which the turbine efficiency is highest. The turbine captures a portion of the available power, referred to as the coefficient of performance C.

IV. SYSTEM CONFIGURATION AND MODULES

The diagram depicts the complete solar panel and wind turbine configuration, as well as a battery arrangement for energy storage with a charge controller.

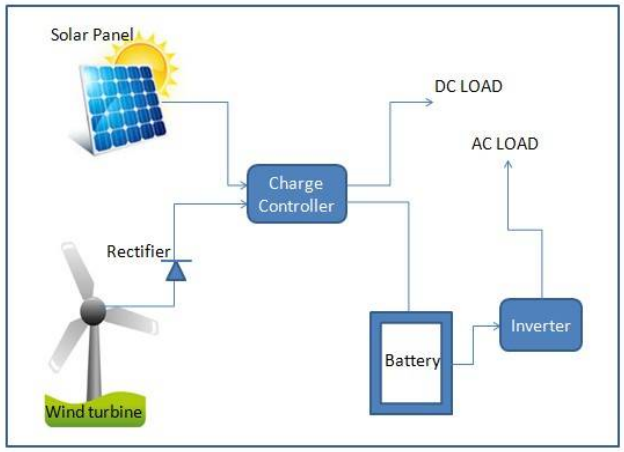

Fig 1: Hybrid Power System Setup

A. *PV Cell Array*

When exposed to sunlight, a photovoltaic cell generates current and a pair of electron holes, whereas photovoltaic cell equipment captures photons with an energy greater than the bandgap of the material. When an external circuit is connected to the cell, photons are generated, which act as carriers, removing the cell's internal electrical fields and assisting the current flow. Single Diode Circuit is given below:

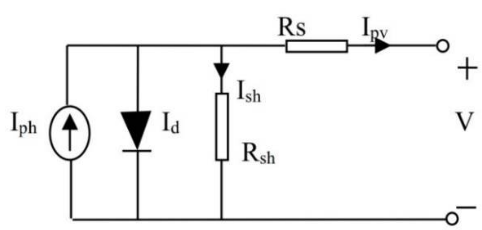

Fig 2: Single Diode circuit

To characterize a PV cell, two important metrics are usually used. The photon-generated current will flow out of the cell as a short-circuit current if the terminals of the cell are shorted together (Isc). As a result, Iph = Isc. The photon-generated current is shunted internally by the intrinsic p-n junction diode when there is no connection to the PV cell (open-circuit). This gives the open-circuit voltage (*Voc*). The output current (*I*) from the PV cell is found by applying Kirchhoff's current law (KCL).

$$I = Isc - Id \qquad (1)$$

Where Id is the current shunted through the intrinsic diode, and Isc is the short-circuit current equal to the photon-generated current. The diode current *Id* is given by Shockley's diode equation:

$$Id = Io\left(e^{\frac{qV}{kT}} - 1\right) \qquad (2)$$

Where Io is the diode's reverse saturation current (A), q is the electron charge (1.60210-19 C), Vd is the diode's voltage (V), k is the Boltzmann's constant (1.38110-23 J/K), and T is the junction temperature in Kelvin (K).
The current-voltage relationship of the PV cell is obtained by substituting the equation for Id in the equation.

$$I = Isc - Io\left(e^{(qV}/kT) - 1\right) \qquad (3)$$

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Under constant temperature, the reverse saturation current of a diode (Io) is constant and can be calculated by setting the open-circuit state. Let I = 0 (no output current) in the equation and solve for Io.

$$0 = Isc - Io\left(e^{\frac{qV}{kT}} - 1\right) \quad (4)$$

$$Isc = Io\left(e^{\frac{qV}{kT}} - 1\right) \quad (5)$$

The reverse saturation current of a diode (Io) is constant at constant temperature and can be computed by setting the open circuit state. In the equation, set I = 0 (no output current) and solve for Io.

B. Wind Turbine

The WT uses a torque applied to a drive train to convert wind energy to mechanical energy. To analyze the torque and power generation for a particular wind speed, as well as the effect of wind speed fluctuations on the produced torque, a WT model is required. Within the interval [Vmin, Vmax], where V is the mean wind speed, the torque Twt and power Pwt produced by the WT are functions of the WT blade radius R, air pressure, wind speed, and coefficients Cq and Cp.

$$Twt = \frac{1}{2}\rho\pi R^3 Cq(\lambda,\theta)V^2 \quad (6)$$

$$Pwt = Cp(\lambda, \theta) \quad (7)$$

$$Pv = 1/2\rho R^2 Cp(\lambda, \theta)V^3 \quad (8)$$

Cp stands for power coefficient and describes the WT's ability to extract energy from the wind. Cq is the torque coefficient, and it is related to CP by the formula Cq=Cp/ λ, where the tip ratio is:

$$\lambda = \frac{\omega_{wt}R}{v} \quad (9)$$

We did not employ MPPT, but we did determine the optimal resistance value in simulation to produce the best power output.

V. SOLAR WIND HYBRID SIMULATION USING MATLAB

This configuration was modelled using Simulink and Simscape. The following are some of the model's components:

- Solar panel with ten solar cells connected in series and a 1.29 amp short circuit current.
- open circuit voltage of 2.1 volts (2.1*10 = 21 Volts).
- Diodes are devices that allow current to flow in just one direction.
- A voltmeter and an amp meter are attached to read the voltage and amperage coming from the solar panel, and a product of the two is used to measure the PV and windmill power production.

A. Simulated Solar Panel using the Optimal Value of the Resistance for the Best Power

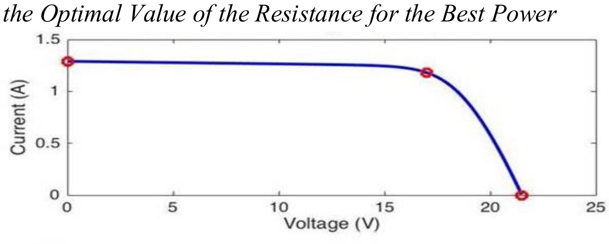

Fig 3: output of Solar panel (I vs V)

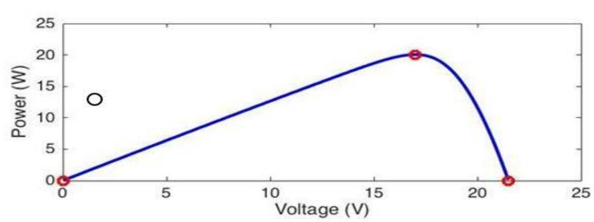

Fig 4: output of solar panel (V vs P)

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The solar panel's maximum power point was achieved at 17 volts and a current of 1.29 amps, consuming 21 watts.

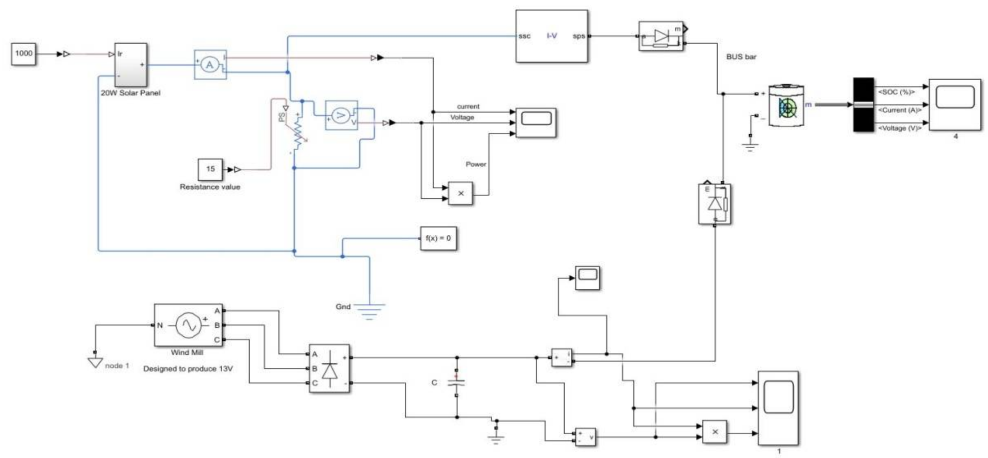

Fig 5:Simulink circuit for a hybrid power system

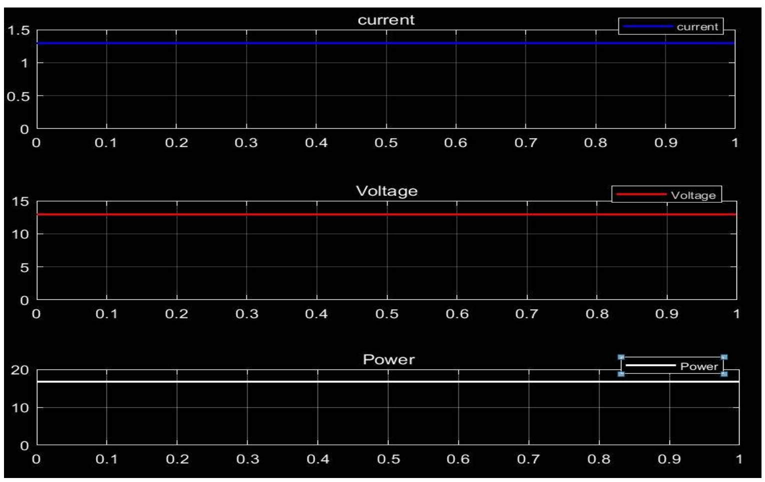

Fig 6: Solar panel simulation result

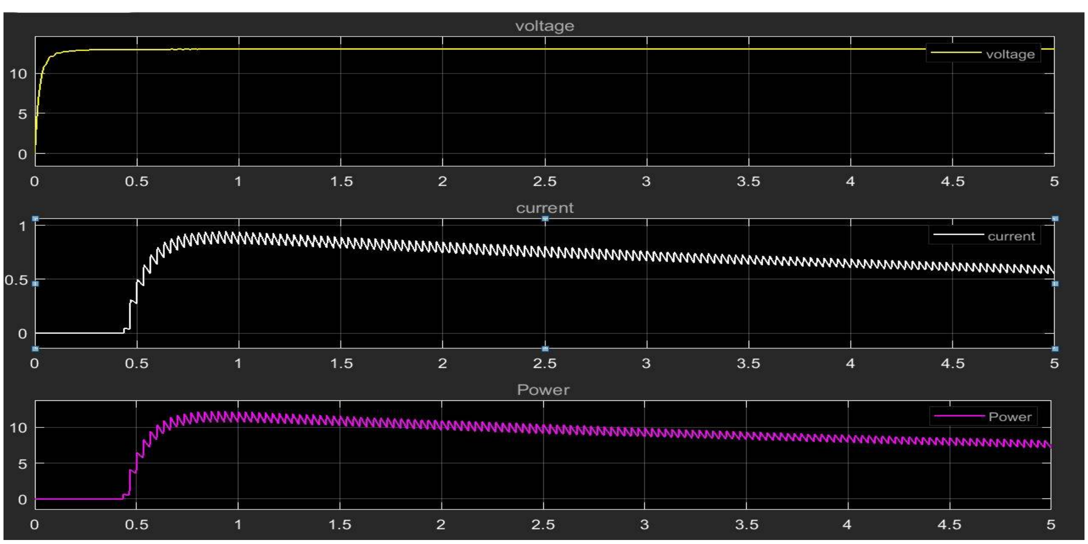

Fig 7: the outcome of a wind source simulation

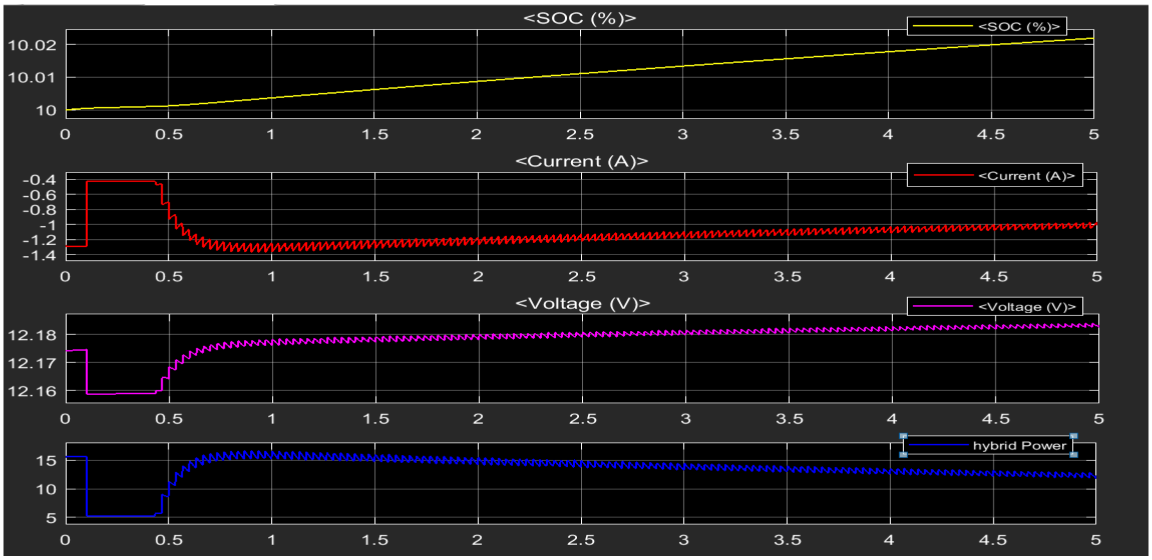

Fig 8: Output of a hybrid power system

VI. CONCLUSION

The goal of this article is to demonstrate the efficiency, dependability, and maximum power generation of a hybrid power system by combining a wind turbine system with a solar photovoltaic system. Because of the decreasing cost of PV and wind generators in recent years, HRES is becoming more popular for remote and rural electrification. It is expected to play a key role in bringing power to the bulk of the world's 1 billion people who do not have access to it, primarily in developing countries. Rather than relying on a single generation system like PV or Wind, HRES may gather energy even when the potential is low, improving power reliability We can also utilize MPPT in this case. The MPPT controller calculates the optimal voltage for maximum power output and converts higher voltages to the required optimal value, resulting in maximum power output. For example, if a solar panel is rated to produce 20 watts but only delivers 14 volts and 1.2 amps, the output is only 16.8 watts. When employing MPPT, it estimates at what voltage this voltage can provide us with the most power and uses voltage converters to keep the voltage at that reading.

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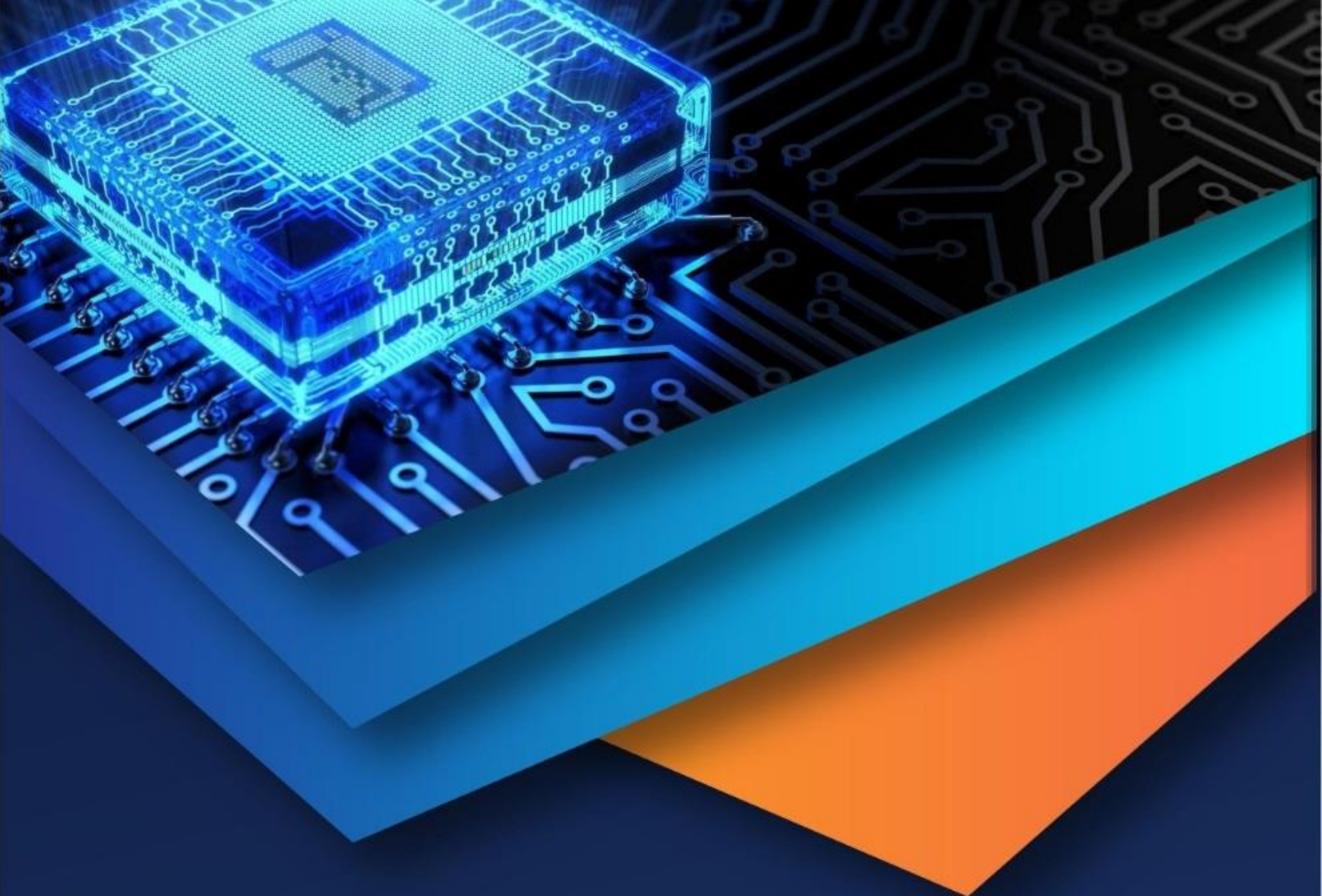

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